

Practice Problems in Mendelian Genetics

Important Note: Get in the habit right from the first of writing down the work necessary to solve the problems you do. You will be required to show work on any assignment or exam problem.

I. Problems Involving One Gene

1. In cats, long hair is recessive to short hair. A true-breeding (homozygous) short-haired male is mated to a long-haired female. What will their kittens look like?
2. Two cats are mated. One of the parent cats is long-haired (recessive allele). The litter which results contains two short-haired and three long-haired kittens. What does the second parent look like, and what is its genotype?
3. Mrs. And Mr. Smith both have widow's peaks (dominant). Their first child also has a widow's peak, but their second child doesn't. Mr. Smith accuses Mrs. Smith of being unfaithful to him. Is he necessarily justified? Why or why not? Work the genetics problem predicting the frequencies of the versions of this trait among their prospective children.
4. Mr. and Mrs. Jones have six children. Three of them have attached earlobes (recessive) like their father, and the other three have free earlobes like their mother. What are the genotypes of Mr. and Mrs. Jones and of their numerous offspring?
5. Mr. and Mrs. Anderson both have tightly curled hair. (The hair form gene shows incomplete dominance. There are two alleles, curly and straight. The heterozygote has wavy hair.) The Andersons have a child with wavy hair. Mr. Anderson accuses Mrs. Anderson of being unfaithful to him. Is he necessarily justified? Why or why not?
6. Two wavy haired people (one male and one female) marry and have eight children. Of these eight, how many would you expect to be curly haired, how many wavy haired and how many straight haired, assuming that the family follows the expected statistically predicted pattern? Suppose you examine the actual children and discover that three of the eight have curly hair. What do you suppose went wrong?
7. Basic body color for horses is influenced by several genes, one of which has several different alleles. Two of these alleles—the chestnut (dark brown) allele and a diluting (pale cream) allele (often incorrectly called 'albino')—display incomplete dominance. A horse heterozygous for these two alleles is a palomino (golden body color with flaxen mane and tail). Is it possible to produce a herd of pure-breeding palomino horses? Why or why not? Work the Punnett's square for mating a palomino to a palomino and predict the phenotypic ratio among their offspring.
8. In certain portions of the Jewish population, there is a genetic disease called Tay Sachs disease, which is fatal to infants within the first five years of life. This disease is caused by a recessive allele of a single gene. Why does this disease persist, even though it is **invariably** fatal long before the afflicted individual reaches reproductive age? (In other words, why doesn't the allele for Tay Sachs disease simply disappear?)

9. About 80% of the human population can taste the chemical phenylthiocarbamide (PTC), while the other 20% can't. This characteristic is governed by a single gene with two alleles, a tasting allele and a non-tasting allele. What does this statistic tell us about which allele (tasting or non-tasting) is dominant?
10. In fruit flies, the gene for wing shape has an unusual allele called 'curly' (designated 'Cy'). The normal (wild type) allele is designated 'cy.' A fly homozygous for cy (cy cy) has normal, straight wings. The heterozygote (Cy cy) has wings which curl up on the ends (and, incidentally, can't really fly). The homozygote for the Cy allele (Cy Cy) never hatches out of the egg. In other words, this allele is lethal in the homozygous condition. If two curly winged flies are mated, and the female lays 100 eggs, predict the following, showing appropriate work:
 - a. How many eggs will produce living offspring?
 - b. How many straight winged flies do you expect among the living offspring?
 - c. What percentage of the living offspring do you expect to be curly winged like the parents?
11. In cattle, there is an allele called dwarf which, in the heterozygote, produces calves with legs which are shorter than normal. This, again, is a homozygous lethal (the homozygous dwarf calves spontaneously abort early or a stillborn). If a dwarf bull is mated to 400 dwarf cows, what phenotypic ratio do you expect among the living offspring?

II. Problems Involving Two Genes

1. A man with dark (dominant), curly (see problem I.5.) hair marries a woman with light, straight hair. Their daughter, who happens to have dark hair, marries a man with light, wavy hair. Answer the following questions about this dark-haired daughter and her family.
 - a. Draw a Punnett's square for this marriage, and predict the phenotypic ratio among the offspring of the daughter and her husband.
 - b. What is the chance that they will have a child with hair just like his or her father's?
2. In cats, again, black color is dominant to a special, temperature-sensitive albino gene which produces cats with dark legs, faces and tails (Siamese cats, in case you don't recognize it). A short haired (dominant) Siamese colored female is bred to a long-haired black male. They have eight kittens: 2 black, short-haired; 2 black, long-haired; 2 Siamese, short-haired; and 2 Siamese, long-haired. What were the genotypes of the two parents?
3. Elizabeth is married to John, and they have four children. Elizabeth has a straight nose (recessive) and is able to roll her tongue (dominant). John is also able to roll his tongue, but he has a convex (Roman) nose (dominant). Of their four children, Ellen is just like her father, and Dan is just like his mother. The other children—Anne, who has a convex nose, and Peter, who has a straight nose—are unable to roll their tongues. Please answer the following questions about this family.
 - a. What are the genotypes of Elizabeth and John?
 - b. Elizabeth's father was a straight-nosed roller, while her mother was a convex-nosed non-roller. What can you figure out about **their** genotypes?
 - c. John's father was a straight-nosed roller, while his mother was a convex-nosed roller. What can you determine about their genotypes?
 - d. Diagram the three described generations of this family in accepted pedigree form, including the phenotypes for these two traits.

4. If a pure-breeding (homozygous) black (dominant), long-haired (recessive) cat is mated to a pure-breeding Siamese, short-haired cat, and one of their male offspring is mated to one of their female offspring, what is the chance of producing a Siamese colored, short-haired kitten?
5. In horses, one which runs best in water (or in wet conditions) is called (WATER), and one which runs best in dry conditions is called (DRY). (WATER) is recessive to (DRY). A horse can also be either a trotter, which we will designate (GAIT) or a pacer, which we will designate (PACE). (PACE) is recessive to (GATE). We have mated two horses, a stallion named Halter-Man and a mare named Erlich-Mane. Halter-Man is a (WATER)(PACER), while Erlich-mane is a (DRY)(GAIT). One of Erlich-Mane's parents was a (WATER)(PACER). What are the chances of Erlich-Mane and Halter-Man producing a (WATER)(GAIT) foal (that's a baby horse, in case you didn't know)?
6. When a male pig from a line of true-breeding (homozygous) black, solid-hooved pigs was crossed to a female from a breed (homozygous) of red, cloven-hooved pigs, their several progeny all looked alike with regard to color and hooves. These progeny were all mated to members of the same breed as their red, cloven-hooved mother pig. The offspring from this final cross were: 11 black, cloven-hooved; 8 black, solid-hooved; 14 red, cloven-hooved; and 10 red, solid-hooved. For each of these two genes (coat color and hoof type) determine which allele is the dominant one. Explain your reasoning. What were the phenotypes of the progeny produced by the first mating in this problem?
7. In garden peas, long stems are dominant to short stems, and yellow seeds are dominant to green seeds. 100 long/yellow pea plants, all of which had one short/green parent, are interbred (bred to each other). 1600 progeny result. Please answer the following questions about these progeny.
 - a. Assuming that these two genes are unlinked, about how many long/green pea plants would you expect to find among the offspring?
 - b. What ratio of yellow to green seed color would you expect among the offspring?
 - c. What would you expect the overall phenotypic ratio among the 1600 offspring to be (taking into consideration both traits)?

III. Problems Involving Sex Linkage

1. Plutonian Tickle-bellies have a sex determination system just like mammals. Hairy Snout is a holandric trait (carried on the Y chromosome). MyxRotcccc, a handsome male Tickle-belly, has lovely orange hair on his snout. He and his mate, OrgggWny, have six offspring, three boys and three girls. Please answer the following questions about this family.
 - a. How many of MyxRotcccc's and OrgggWny's offspring have hairy snouts? Can you predict which ones?
 - b. Their eldest son, Bob, marries and has a son. What is the chance that Bob's son will also have a hairy snout?
 - c. JoKchew, MyxRotcccc's and OrgggWny's youngest daughter, marries a male who has a smooth, hairless purple snout. She has eight offspring, each one lovelier than the last, and all boys. What percentage of these offspring do you expect to have hairy snouts? Explain.
2. In fruit flies (*Drosophila*), one eye color gene is X-linked, with a recessive white allele and a dominant red allele. If white-eyed female flies are bred to red-eyed male flies, describe the expected offspring (assume all parental flies are true-breeding). What results do you expect if you do the **reciprocal cross** (reverse the phenotypes of the parent flies)?
3. Earl has normal color vision, while his wife Erma is colorblind. . Colorblindness is an X-linked trait, and the normal allele is dominant to the colorblindness allele. If they have a large family, in what ways should the colorblindness trait affect their children?
4. Ethan is colorblind. His wife, Edna, is homozygous for the normal color vision allele. If they have eight children, how many of them would you expect to be colorblind? Using Punnett's squares, derive and compare the genotypic

and phenotypic ratios expected for the offspring of this marriage and those expected for the offspring of the marriage described in III.3.

5. Marian's father is colorblind, as is her maternal grandfather (her mother's father). Marian herself has normal color vision. Marian and her husband, Martin, who is also colorblind, have just had their first child, a son they have named Mickey. Please answer the following questions about this small family.
 - a. What is the probability that this child will be colorblind?
 - b. Three sources of the colorblindness allele are mentioned in this family. If Mickey is colorblind, from which of these three men (Marian's grandfather, Marian's father, or Martin) did he inherit the allele?
 - c. Using proper pedigree format, diagram the available information about the four generations of this family described, assuming that Mickey is colorblind.
 - d. If Martin were not colorblind, how would this affect the prediction about Mickey?
6. In cats, there is a coat color gene located on the X chromosome. This gene is a different gene from the black/Siamese gene discussed in earlier problems. This gene has two alleles—orange and black. A heterozygous cat has tortoiseshell color (a splotchy mixture of orange and black). Predict the genotypic and phenotypic frequencies among the offspring of the following crosses. Pay careful attention to the **genders** of the offspring.
 - a. Black female X Orange male
 - b. Orange female X Black male
 - c. Tortoiseshell female X Black male
 - d. Tortoiseshell female X Orange male

IV. Problems Involving Genes With Multiple Alleles

1. In a particular family, one parent has Type A blood, the other has Type B. They have four children. One has Type A, one has Type B, one has Type AB, and the last has Type O. What are the genotypes of all six people in this family?

NOTE: The ABO blood type gene has three alleles. I^A and I^B are codominant; i (for Type O) is recessive to both.

2. Refer to problem I.3. Mrs. Smith has blood type A. Mr. Smith has blood type B. Their first child has blood type AB. Their second child has blood type O. **Now** is Mr. Smith justified? What are Mr. and Mrs. Smith's genotypes for these two genes?
3. In a recent case in Spokane, Washington, a young woman accused a soldier of being the father of her child. The soldier, of course, denied it. The soldier's lawyer demanded that blood types be taken to prove the innocence of his client. The following results were obtained: Alleged father, Type O. Mother, Type A. Child, Type AB. The court found the soldier guilty on the basis of the woman's remarkable memory for dates and details that apparently eliminated all other possible fathers.
 - a. What are the possible genotypes for these three people?
 - b. Do you agree with the court's decision? Why or why not?
4. It was suspected that two babies had been exchanged in a hospital. Mr. and Mrs. Jones received baby #1 and Mr. and Mrs. Simon received baby #2. Blood typing tests on the parents and the babies showed the following:

Mr. Jones: Type A	Mr. Simon: Type AB
Mrs. Jones: Type O	Mrs. Simons: Type O
Baby #1: Type A	Baby #2 Type O

Were the babies switched? How do you know whether they were or they weren't?

5. A man with type O blood marries a woman with Type AB blood. Among their children, what proportion would you expect to have blood types like one or the other of these parents? What proportion would have expect to have blood types different from both parents? Explain.
6. You are a scientist performing the first analysis of the genetic basis for the inheritance of flower color in a certain species of wildflower. You begin your investigation by observing that there are four different flower colors in the local wild population: white, red, blue and purple. Your first assumption (hypothesis) is that you are looking at the effects of a single gene, so operate under that assumption. You collect a variety of samples of all colors, take them back to your greenhouse, and begin making crosses. Remember, you are crossing members of a wild population—you have no idea whether any of your plants are homozygous or heterozygous. Here are the various results you observe:

White X White	All offspring always produce white flowers.
Red X Red	In some matings, all offspring produce red flowers. In other matings, some of the offspring produce red flowers, some white, with red flowering offspring outnumbering white flowering offspring.
Blue X Blue	In some matings, all offspring produce blue flowers.. In other matings, some of the offspring produce blue flowers, some white with blue flowering offspring outnumbering white flowering offspring.
Purple X Purple	Always produces a mixture of red, blue and purple flowering offspring, with purple most frequent, followed by red and blue in roughly equal numbers,
White X Red	In some matings, all offspring produce red flowers. In other matings, some of the offspring produce red flowers, some white. Red and white occur in roughly equal numbers..
White X Blue	In some matings, all offspring produce blue flowers. In other matings, some of the offspring produce blue flowers, some white. Blue and white occur in roughly equal numbers..
White X Purple	Always produces roughly equal numbers of blue flowering offspring and red flowering offspring.
Red X Blue	Always produces purple offspring, but in some matings also produces red and/or blue offspring, and/or white offspring
Red X Purple	Always produces red and purple offspring, sometimes mixed with blue.
Blue X Purple	Always produces blue and purple offspring, sometimes mixed with red.

- a. How many alleles are governing flower color in this plant? What color does each of these alleles produce (in other words, what colors are your homozygous plants)?
- b. Explain the dominance relationships among your alleles, and explain the results of each of the crosses described above.

NOTE: This problem has a relatively high difficulty level.

7. A woman has a daughter. There are three men whom she claims might have been the father of the child. The judge in the paternity court orders that all three men, the child, and the mother have blood tests. The results are: mother, Type A; Daughter, Type O; Man #1, Type AB; Man #2, Type B; Man #3, Type O. The mother claims that this proves that Man #3 must be the little girl's father.
 - a. Is the mother correct? Why or why not?
 - b. The judge isn't satisfied, so he asks for the medical records of the people involved. He discovers that the little girl is colorblind. Men #'s 1 and 2 are also colorblind; Man #3 has normal color vision, as does the mother. (NOTE: Colorblindness is X-linked and recessive.) Assuming that one of these three men **must** be the father, can you now determine which of the three it is?

8. Another woman has the same problem. Her blood type is A, her child's is B. She again has three candidates for fatherhood. Their blood types are: Man #1, B; Man #2, AB; Man #3, O. Based on blood types, the mother says it must have been #1.
- Do you agree? Why or why not?
 - This child, a son this time, is also colorblind. The only one of the men in question to share this characteristic is #2. The mother is not colorblind. Can you now determine who the father of the little boy is, assuming it must be one of these men? Explain your answer.

Problems Involving Gene Interactions

- In cats, there is a gene which produces ticked fur (bands of different colors on each hair) called Agouti (H). The recessive allele (h) for this gene produces hair which is a solid color from end to end. In addition, there is a coat color gene which has a recessive albino allele (a) which, in the homozygote, prevents the production of any coat color pigment, resulting in a white cat with pink eyes, the traditional albino. Note that this problem has described two completely different genes. These genes are unlinked. An albino female cat is mated to a solid brown male cat. All of their offspring are Agouti. The males and females among these offspring are allowed to freely intermate, producing a flock of F₂ kittens. Predict the phenotypic ratio for fur color among these many grandkittens.
- In *Drosophila* (fruit flies), the wild type eye color, brick red, is actually produced by the deposition of two pigments in the eyes, a dull brown pigment and a brilliant red pigment. These two pigments are produced by the action of two different, non-allelic (and non-linked) genes. Each of these genes has two alleles, a dominant one which causes normal the production of the pigment controlled by the gene, and a recessive one which is defective, and causes none of that pigment to be produced. Thus, a normal eye-color fruit fly must have at least one dominant allele for each of these genes.

If a fly is homozygous for the defective, recessive allele of the gene which produces the brown pigment, that fly will have only the brilliant red pigment in its eyes. This condition is called "cinnabar." For this reason, the gene responsible for producing the brown pigment is called the "cinnabar" gene (genes are often named for the effect their mutant alleles have on the phenotype). The symbol for this gene is a two-letter symbol, cn. The dominant allele is **Cn** and the recessive allele is **cn**. Careful with this symbol. Never separate the c's from the n's. So a cinnabar-eyed fly would have the genotype **cn cn**.

If a fly is homozygous for the defective, recessive allele of the gene which produces the brilliant red pigment, that fly will have only the dull brown pigment in its eyes. This produces "brown" eyes, so this gene is called the "brown" gene. The symbol for this gene is br. The dominant allele is **Br**, the recessive **br**. A brown-eyed fly would be **br br**. Again, be careful not to separate the b and the r.

Note that all flies have two alleles for **each** of these genes, so the cinnabar eyed fly would actually have the genotype **cn cn Br Br** or **cn cn Br br**, and the brown eyed fly would actually have the genotype **Cn Cn br br** or **Cn cn br br**.

A mating is made between a **Cn Cn br br** fruit fly and a **cn cn Br Br** fruit fly. 200 offspring result (the F₁). These offspring are allowed to freely interbreed, and produce 40,000 (whew! Whatever happened to population control!) offspring (the F₂).

- What color eyes did the original parents have?
- What were the genotypes and phenotypes of the F₁ offspring?
- What color eyes do the **cn cn br br** flies have?
- What phenotypic ratio do you predict among the F₂ offspring?